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In the year 1925, and again in 1927, a study in cooperation with the State workers was made to determine, if possible, our more important insect pests. The results of these studies indicated clearly that the judgment of entomologists as to the relative importance of different insects was decidedly biased by the work that they had immediately under way.

Estimates on the damage done by insects are numerous. The most comprehensive of these* have served as a standard since that time. The difficulty encountered in arriving at any degree of accuracy has hampered this type of endeavor.

It is quite necessary, however, that we have at least a generalized conception of the economic status of our several pests. The control of insects involves the expenditure of money, and unless we have figures regarding the monetary loss caused by them, we can get no definite idea as to the benefits in terms of dollars derived from control measures.

With such figures, we have only to subtract the cost of control from the estimated loss to learn whether or not, in a particular case, our methods of control are worth while. In the case of pests of long standing, and on which repressive measures have been used for many years, only the estimated losses in cases where control has been neglected will give an idea of the saving effected. To single these cases out over a large area would be a difficult task, and the "loss estimates" usually do not make this distinction.

This monetary loss is affected by many factors that tend to reduce the accuracy of the estimates. For instance, supply and demand fix prices, and the reduction of a crop by an insect pest automatically raises the price if the price of that crop is not fixed by a world market. There is a decided fallacy, therefore, in trying to estimate the money returns that

* Marlatt, C. L., The annual loss occasioned by destructive insects in the United States. U. S. Dept. Agr., Yearbook for 1904, p. 461-474, 1905.

Marlatt, C. L., Losses due to insects. Part I. Insects as a check on agricultural production and as a source of waste to accumulated supplies. National Conservation Commission Rept., vol. 3, p. 301-309. 1909.

would have been received for the crop had the insect been completely controlled. If such an estimate is based on the price of the reduced crop, it may be entirely erroneous, and in any case there is no way of making it accurate, for we do not know what the price would have been. Climatic conditions also materially affect crop production. The control of one insect at times interferes with the control of another. But despite these many interfering factors, the estimates indicate, in a broad general way, the relative importance of the pests concerned.

The insects treated in this paper are but a small fraction of the total number that are economically affecting our existence. In the files of the Insect Pest Survey there are now recorded 6,000 species of insects that have been reported as of more or less economic importance in the United States, so the total loss of \$924,440,000 occasioned by 34 of our more important pests (Table I) indicates that a previous estimate of over \$2,000,000,000 by all insects is extremely conservative.

Many of the more recently introduced pests, such as the European corn borer, the alfalfa weevil, the oriental fruit moth, and the Japanese beetle, are not included in this estimate because their place in our fauna is not yet well enough established to indicate what damage they will eventually occasion.

BOLL WEEVIL

Damage by the boll weevil (Anthonomus grandis Boh.) has been estimated by the crop reporters of the Bureau of Agricultural Economics over the 19-year period 1910 to 1928 at an average annual loss of 12 per cent of the cotton crop. (Table II.) The average annual cotton production in the United States for the past three years was 14,000,000 bales, valued at \$1,200,000,000. The workers at the agricultural experiment stations and the State departments of agriculture of the Cotton States have estimated the damage by this insect at an even higher figure. The South Atlantic States estimate the loss at 22 per cent and the lower Mississippi Valley States at 19 per cent. Accepting the more conservative estimate of the longer period, we find that the 14,000,000-bale crop is only 88 per cent of the crop of 15,900,000 bales that might have been harvested had it not been for this one insect- a loss occasioned by the boll weevil of 1,900,000 bales valued at \$163,000,000, ignoring the depression of cotton prices that would have been produced had this extra cotton come on the market.

Much of the cotton crop at the present time is being dusted to control the boll weevil. A summary of airplane operations, though by no means complete, indicates that during one season about a quarter of a million acres of cotton were dusted in this manner, and the acreage dusted by ground machinery is much larger. On account of the very large part of the cotton crop that is not dusted annually, or is dusted only once, the general average rarely exceeds two treatments per year. Average dusting costs only \$2 per acre, and this can be added to the damage occasioned by this insect. Of the 44,000,000 acres devoted to this crop, about 750,000 acres were dusted in 1929 at a cost of \$1,500,000.

BOLL WORM OR CORN EAR WORM (Heliothis obsoleta Fab.)

The crop reporters of the Bureau of Markets have estimated that over a 19-year period, 1910-1928, insects other than the boll weevil destroyed 4 per cent of the cotton crop. Quaintance and Brues (Bur. Ent. Bul. 50, 1905) estimated the approximate annual loss to the cotton crop by the boll worm in Texas, Louisiana, Mississippi, Oklahoma, and Arkansas, the States in which boll worm injury to cotton was most severe, as 4 per cent, and observed from 8 to 60 per cent loss to cotton by the boll worm in Texas in 1903 and 1904. B. R. Coad, believes that damage by miscellaneous cotton insects other than the boll weevil and the boll worm amounts to at least 2 per cent. This would leave 2 per cent of the damage attributable to the boll worm. That is, the 14,000,000-bale crop is but 98 per cent of the crop to be expected without the boll worm and the loss would amount to over 280,000 bales or a monetary loss of \$24,000,000.

Heliothis obsoleta Fab. is known as the corn ear worm when it attacks corn. In the far South, sweet corn is not generally grown on account of the boll worm. In a central belt, including Delaware and Maryland, and westward to Illinois, from 10 to 50 per cent of the crop is destroyed by this insect and often the infestations are so severe that the entire, canning crop is rejected at the canneries. In 1900, Quaintance and Brues (Bur. Ent. Bul. 50, 1905), estimated that 25 per cent of the sweet corn was injured in the cannery sections alone. The 1927-1929 corn pack averaged 14,000,000 cases of 24 cans each per year, about 7,000,000 of which were from the boll-worm belt. If this is only 75 per cent of the potential crop that would have been raised but for the insect in this area, the damage was over 2,000,000 cases; the money loss is roughly \$4,000,000, besides loss to sweet corn marketed in the ear.

The damage to field corn, though less severe than to sweet corn, amounts in the aggregate to a much larger figure. The same investigators (Quaintance and Brues, loc. cit.) found that individual larvae fed in the laboratory consumed 40 kernels of corn each during their period of growth. Allowing 900 kernels to the average ear, this would mean a loss of 4.5 per cent.

Corn-ear-worm investigations carried on in Nebraska by Swenk indicated that in 1908 certain fields were 100 per cent infested and practically 50 per cent of the grain was actually consumed. Usually in this State, however, infestations run between 40 and 75 infested ears per 100, and the total grain consumed was approximately 4 per cent of all ears.

Intensive study carried on by Dean and McCulloch in Kansas for twenty years indicates that the annual percentage of ears infested is approximately 75 per cent and rarely drops below 50 per cent, and counts of the kernels of several thousand ears indicate that the corn actually consumed amounted to 4 per cent of the kernels on the infested ears.

The State and station workers in the Corn Belt have estimated the damage by this insect as increasing very materially from the North southward. The Middle Atlantic States estimate 5 per cent; the South Atlantic, 4 per cent (the writer believes, however, that this is a very inaccurate estimate and far below the actual damage in this region); the East Central States, 3 per cent; the West Central States, 5 per cent; and the lower Mississippi Valley, 10 per cent. This would give an average damage over the entire Corn Belt of over 6 per cent.

Adopting the more conservative estimate of loss, based on extensive field investigations, of 4 per cent, our corn crop, based on the 3-year average, 1927-1929, of 2,700,000,000 bushels per annum, would be only 96 per cent of that which might have been obtained were it not for this one insect, or 2,800,000,000 bushels, making a loss of 100,000,000 bushels. Placing the value at the 3-year average for 1927-1929, 75.2 cents per bushel, the monetary loss would be \$75,200,000.

Tomatoes over the greater part of the Southern States are seriously attacked by this insect. Quaintance and Brues (Op. Cit.,) estimated the damage to tomato fruit at 2 per cent. The tomato crop of the United States for the 2-year period, 1928-1929, averaged 1,620,000 tons per year and was valued at \$46,000,000. Although this insect is not a serious tomato pest over the entire tomato-growing area, about half of the tomato acreage in the United States, located in that strip of territory extending from Texas across the southern part of the United States to Maryland, is seriously infested. Two per cent of half of the total tonnage would amount to 16,200 tons or a monetary loss of \$460,000. Totaling the losses occasioned by this insect, we have:

Field corn.....	\$ 75,200,000
Cotton	24,000,000
Sweet corn	4,000,000
Tomatoes	460,000
Total	\$103,660,000.

HESSIAN FLY

McColloch and Dean carried on very extensive investigations of the Hessian fly (Phytophaga destructor Say) in Kansas from the years 1923-1927 in which field observations gave the following results:

The damage for-	Amounted to Bushels
1923	8,000,000
1924	20,000,000
1925	40,000,000
1926	5,000,000
1927	20,000,000

This amounts to Hessian fly damage of approximately 15 per cent of the crop usually harvested in that State.

The experiment stations and the State entomologists of the East Central States have estimated the annual loss occasioned by this insect at 13 per cent; and the workers in the Middle Atlantic States, at 6 per cent. The winter wheat crop of Michigan, Wisconsin, Missouri, Iowa, and Kentucky may be included in considering that of the East Central States, because produced under similar conditions. If the loss for each region is estimated on the basis of its 1920-1928 winter wheat crops and the above percentages, the three regions will show a total annual loss of 48,000,000 bushels, which, valued at \$1 per bushel, would amount to a monetary loss of \$48,000,000. C. L. Metcalf, in the 55th Annual Report of Entomological Society of Ontario, gives almost three times this figure as the loss occasioned by all insects attacking wheat.

CHINCH BUG

Reviewing the situation of the chinch bug (Blissus leucopterus Say) during the last 50 years, it is found that the average number of counties yearly reported as infested in Kansas, if distributed evenly over the entire period, would amount to 25 per cent of the entire number; in Missouri, the data are much less satisfactory, and we have an average of 9 per cent annually; in Illinois 18 per cent, and six per cent in Indiana, and an average over the entire territory of about 14 per cent infested annually to the extent of causing complaint. This belt produces about \$550,000,000 worth of corn and \$225,000,000 worth of wheat (estimates for 1927-1929). In the infested territory, wheat is often severely injured by this insect during the outbreak years; and corn, in fields where the insect is not checked by control practices, is sometimes a complete loss.

The value of 14 per cent of the wheat in this territory is over \$30,000,000 per year at prevailing prices from 1927 to 1929; 14 per cent of the corn crop would amount to \$77,000,000 at 1930 corn prices. With an estimate of 50 per cent loss during outbreaks, the average annual loss occasioned by this insect would be over \$50,000,000. While loss does not always reach 50 per cent, it sometimes exceeds it; the chinch bug causes some loss in counties not reported as infested and in other States; \$50,000,000, therefore, seems a fair estimate.

SUGARCANE BORER

The sugarcane borer (Diatraea saccharalis Fab.) is undoubtedly the most important pest to sugarcane in this country. Messrs. Holloway and Haley estimate that the damage to sugarcane due to this insect over a series of years amounts to approximately 19 per cent. Converted into sugar, this amounts approximately to a loss of 58,000 tons. At a price of four cents per pound, this reaches \$4,640,000. No account is taken of the loss to cane used for sirup, nor to seed pieces of sugarcane.

APPLE APHIDS

Apple aphids are estimated by the entomologists of the States east of the Mississippi River as reducing the apple crop 16 per cent; it seems likely that this estimate applies to outbreak years, and for all years we may reduce it to 6 per cent. The apple crop in this region averages around 85,000,000 bushels annually (1927-1928). This is only 94 per cent of what might have been harvested were it not for these insects, and indicates a crop loss of 5,000,000 bushels with a valuation of nearly \$7,000,000. To this must be added the cost of spraying to prevent a much higher percentage of injury over this entire territory. In this region there are 65,000,000 bearing trees. About 30,000,000 of this number are in commercial orchards, and are sprayed with nicotine sulphate when necessary, or approximately once in three years at an average cost of 12 cents per tree; the amount lost in expenditures would be \$1,200,000. therefore

CODLING MOTH

The codling moth (Carpocapsa pomonella L.) has been very carefully studied by many investigators in this country. A long series of experiments carried on by Quaintance and Scott in Virginia, Delaware, Michigan, Kansas, and Arkansas and experiments carried on by Gossard in Ohio, Rumsey in West Virginia, Felt in New York State, and Jones and Davidson in California indicate that the proportion of unsprayed fruit which was found to be infested by this insect ran from 15 to 74 per cent with an average for all experiments over the entire period of 45.13 per cent. For the triennium 1927-1929, the American apple crop averaged about 150,000,000 bushels of apples annually, valued at over \$180,000,000. Culls and wormy apples are rarely worth more than 50 cents per bushel. Were it not for spraying we could possibly count on an average of 67,500,000 bushels that would have to be sold at a very considerable discount. Estimates received from the State entomologists and the State agricultural experiment station workers throughout the apple-growing States indicate that, even including those orchards which are carefully sprayed, the damage runs to approximately 12 per cent of the fruit. This would occasion a reduction in No. 1 apples of 18,000,000 bushels or a monetary loss of about \$13,500,000. To this must be added the cost of spraying which prevented a much more considerable loss than indicated by the figures already given. To spray an apple tree over the season, charging only for arsenicals and labor, the cost is 35 cents. The number of trees of bearing age in the United States in 1924 was 104,000,000.

In the years 1927-1929, the commercial crop was over half the whole crop. Allowing for a heavier yield in commercial orchards, we may figure the commercial trees which are regularly sprayed as at least half of the total number of trees.

Spraying 50,000,000 trees for the codling moth costs, therefore, \$17,500,000 or a total loss occasioned by this pest of over \$30,000,000. (A new expense, acid washing, to remove excess arsenic amounts to 3 cents per bushel.)

In contemplating these figures and comparing the loss occasioned by this pest and other pests controlled fairly satisfactorily by insecticide methods we must keep in mind that a pest which potentially is extremely serious but which is very effectively controlled by an inexpensive measure will show a smaller loss than a much less potentially important pest that is but poorly controlled or controlled by a very expensive method. In some of these cases the low figure indicates that entomological practice is more generally effective and not that the pest is of minor importance.

PEACH BORER

The peach crop of the United States averaged, during the three years 1927-1929, 53,000,000 bushels valued at over \$62,000,000. One of the most important limiting factors over much of the territory is the peach borer (Aegeria exitiosa Say). It is very difficult to get at the actual damage done by this insect as it very quickly kills the trees and reduction in crop is hard to measure. The use of paradichlorobenzene, a very effective control measure, costs from 5 to 6 cents per tree, depending upon the price of labor. Estimating the cost of labor at \$3 a day, the cost of treating the peach trees now grown in the United States would amount to \$5,900,000. This will give a relative idea of the tax that this insect exacts from the peach grower but it does not include the much greater loss in trees killed. However, as this is considered an extremely economical treatment, the loss that the insect would occasion were it not controlled would probably be many times this figure.

PLUM CURCULIO

The plum curculio (Conotrachelus nemophar Hbst.) has been estimated by the fruit growers of the deciduous fruit belt east of the Rocky Mountains as causing an annual loss to the peach crop of approximately 15 per cent. Apples are not so severely or extensively injured, and we may reduce this figure to 5 per cent for them. Quaintance and Scott, investigating this insect in Delaware, Virginia, Michigan, and Arkansas over a three-year period, 1909-1911, found that in unsprayed check plats the average infestations ran to 44.5 per cent of the fruit. This insect is confined to the region east of the Rocky Mountains, and inasmuch as the peach crop of this region is valued on an average at nearly \$45,000,000 (1927-1929), this insect produces a loss of about \$8,000,000 on peaches. Apples of this region are worth about \$126,000,000 and at 5 per cent curculio damage would be nearly \$7,000,000. Some loss is also caused to other fruits. To this we must add the cost of controlling the insect. The pink application on apples is largely for this pest as far as the arsenical is concerned, so a cost of 5 cents per tree is conservative and would amount to a total cost of \$3,000,000 on apple, peach, plum, and pear. Losses and costs due to this insect on apples and peaches may well total \$17,000,000.

Of course, it would not be correct, in the case of these deciduous-fruit insects, to charge the entire cost of arsenical spraying to any one

pest when that spray is effective for more than one insect or disease. We have, therefore, prorated the cost of spraying among the insects that attack the fruit.

SAN JOSE SCALE

The San Jose scale (Aspidiotus perniciosus Comst.) at one time threatened the entire deciduous fruit industry of this country. Owing to the general practice of spraying, it is not today generally considered as responsible for any very considerable portion of the damage to the commercial fruit crop, although undoubtedly, owing to the lowered vitality of unsprayed trees, a very considerable crop loss is sustained. The most tangible figure on the damage by this pest is the cost of dormant spraying, so generally practiced for its control. Practically 41,000,000 deciduous fruit trees are sprayed in commercial orchards every dormant season for the control of this pest, at a rough cost of 18 cents per tree, or \$7,380,000. Another form of damage occasioned by this insect is the lowered quality of fruit due to spotting.

COLORADO POTATO BEETLE

The Colorado potato beetle (Leptinotarsa decemlineata Say) is a pest that during the past 8 or 10 years has occasioned no very considerable shrinkage in the commercial potato crop, owing, in part, to the highly effective control measures which are now quite generally in practice. Despite this fact, however, in the New England States it is estimated that 15 per cent of the crop is annually destroyed. In the Middle Atlantic and South Atlantic States the damage is much less considerable, but is estimated at 3 and 5 per cent, respectively. In the East Central States the damage is estimated at approximately 10 per cent. In the irrigated potato-growing section of the Northwest, the pest is not generally distributed, and it is not a factor in the early-potato sections of the South Atlantic States.

The average reductions of the main potato crop due to this insect, despite the very effective control measures, is probably 8 per cent, that is to say, the 340,000,000 bushels annually harvested in the States where this insect is a pest, is but 92 per cent of the crop that might be harvested were it not present. This amounts to a loss of about 30,000,000 bushels valued at \$39,000,000. To this amount must be added the cost of spraying potatoes which is generally practiced throughout the commercial potato-growing sections. Charging for the arsenicals and for one-half of the labor (the other half is chargeable to fungous-disease control), it costs roughly \$1.50 per acre to spray potatoes. As the acreage of this crop in the United States is approximately 3,000,000 and as approximately one-tenth of this is sprayed, it costs about \$450,000 to prevent further loss.

POTATO LEAFHOPPER

The potato leafhopper (Empoasca fabae Harr.) and the associated disease, hopperburn, have been among the most serious factors attracting

attention in the potato-growing sections during the past few years. The insect is generally prevalent in some of the most important potato-growing sections of the United States. It is not serious, however, outside of the Middle Western States, Wisconsin, Ohio, Illinois, Indiana, and Michigan, and workers in this region have estimated that the loss to the crop due to this trouble runs from 10 to 18 per cent, or a general average of 14 per cent. The average annual potato crop of these States for the years 1926 to 1928 inclusive amounted to about 80,000,000 bushels. This is only 36 per cent of the crop that might have been harvested were it not for this insect, a loss of 13,000,000 bushels valued at over \$11,000,000 at the rather low regional prices.

PEA APHID

Damage by the pea aphid (Illinoia pisi Kalt.) is estimated, both in the Middle Atlantic States and in the North Central States, by the entomologists and other workers of these regions, at 15 per cent. Mr. J. E. Dudley, as a result of six years' investigations in the cannery-pea section of southern Wisconsin, a section containing practically half of the pea canneries of the State, estimated that during this period the average annual loss from depredations of the pea aphid amounted to 11.66 per cent.

Assuming that 15 per cent of damage occurs in the pea-growing sections of Wisconsin, Illinois, and California, the \$11,797,280 worth of peas raised for all purposes in these States in 1928 was only 85 per cent of the crop that would have been possible were it not for this insect. In other words, there was a loss of \$2,082,000 worth of peas. The pea aphid is also an important factor in New Jersey, Delaware, and Maryland, but only sporadically. Allowing a distributed annual loss in these States of 5 per cent we would have an additional \$63,000. Some losses probably occur in the important market areas of the South Atlantic and Gulf States and in the important canning States of Minnesota, Michigan, New York, and Utah, and there is some injury to clover and alfalfa.

MEXICAN BEAN BEETLE

The Mexican bean beetle (Epilachna corrupta Muls.) is still too new a pest to make possible a fair estimate of the damage that it will in all probability cause. M. F. Howard ascertained that on the check plats at Birmingham, Ala., this beetle removed 48 per cent of the bean foliage. He believes that foliage injury of over 40 per cent at or before the time of blossoming reduces the crop in direct proportion to the amount of defoliation, while on the other hand, green beans can withstand a 25 per cent defoliation without apparent reduction in yield. The 48 per cent defoliation figure obtained at Birmingham is believed to be entirely too high for the entire bean-growing area of the United States. In the eastern area where this insect is generally established, beans occupy approximately 70,000 acres. Of this acreage, nearly 30,000 acres are devoted to dry bean production and produce over 350,000 bushels of beans valued at about \$1,500,000 (1928-1929 estimates).

The remainder of the bean acreage produces approximately 50,000 tons of snap beans valued at about \$3,500,000, a total of \$5,000,000 worth of beans (1928-1929). Twenty-four per cent of this would amount to \$1,200,000, and this we might consider as a very rough estimate of the damage this insect is capable of inflicting.

Spraying to control this pest costs about \$6 per acre, and on 70,000 acres would cost \$420,000.

STRIPED CUCUMBER BEETLE

The striped cucumber beetle (Diabrotica vittata Fab.) is one of the most serious pests of practically all of the cucurbitaceous plants. The growers in the melon and cucumber producing sections of the country estimate the damage by this pest at approximately 9 per cent. This insect is not a pest in the important melon-growing sections of California, although the related species, Diabrotica trivittata Mann., is of economic importance in that region. The value of cucurbits, exclusive of cantaloupe, amounts to \$22,000,000. Nine per cent damage would give a monetary loss of about \$2,000,000.

IMPORTED CABBAGE WORM

The imported cabbage worm (Pieris rapae L.) and a few associated lepidopterous larvae, very materially affect the cabbage and cauliflower crops of this country. These insects, according to Hockett on Long Island, reduce the cabbage crop about 3 per cent and reduce the value of the crop harvested approximately 10 per cent owing to the reduction in grade. The entomologists of the principal cabbage-producing States estimate this damage at approximately 18 per cent. Following Hockett, the 3 per cent shrinkage of the crop of 1,027,000 tons of cabbage (1928-1929 average) amounts to about 3,200 tons; at \$22 per ton this is \$700,000 and of the crop that was actually harvested there is a reduction in value of 10 per cent or a loss of over \$2,000,000, a total loss of nearly \$3,000,000 occasioned by this insect and its associates, the cabbage looper (Autographa brassicae Riley) and southern cabbage worm (Pieris protodice B. & L.).

FOREST INSECTS

The damage by insects affecting forest trees and their products may be divided for our purpose into four categories: First, bark beetles in the West; second, the spruce budworm in the Northeast; third, other defoliators throughout the country; and, fourth, those insects which damage forest products after they leave the woods.

One of the most serious forest-insect pests of the West Coast and Rocky Mountain region is Dendroctonus brevicornis Lec., in its attacks on the western yellow pines. The Forest Service estimates that there are 76,000,000,000 board feet of this timber now standing in Oregon. Work carried on by the Bureau of Entomology for the past ten years indicates

that in certain territory there is an average annual depletion in timber of 1.3 per cent. This, however, is a severely infested district. In areas where the infestation has more of an endemic character the average annual loss is about 0.34 per cent of the stand, and it is estimated that 0.75 per cent is a fair figure of the annual loss over the entire yellow pine area of Oregon. That means 570,000,000 board feet which at a value of \$4 per thousand amounts to \$2,280,000 per annum. In the Modoc National Forest and surrounding private timberland surveys carried on by the Bureau of Entomology for the period 1921-1927 showed losses as high as 3 per cent during the season of 1927 with an average for the period of 1.3 per cent, and on certain limited acreages losses have run as high as 50 per cent of the stand or as high as 14 per cent in a single year.

In the Kaibab National Forest the Black Hills beetle (Dendroctonus ponderosae Hopk.) between 1920 and 1925 destroyed approximately 15 per cent of the timber or 150,000,000 board feet per year. This is unavailable timber at present but it has a high future potential value.

Considering all of the western pines, spruce, Douglas fir, and similar trees, damage by bark beetles, (Dendroctonus spp.) has ranged from 5,000,000,000 to 6,000,000,000 board feet per annum, valued at from \$15,000,000 to \$18,000,000.

The spruce budworm (Harmoloba funiferana Clem.) in the northeastern pulpwood sections, embracing Maine and eastern Canada, during a 10-year period ending in 1920 destroyed 25 years' supply of pulpwood (National Program for Forest Reservations, by the American Tree Association, 1926). Pulpwood is roughly valued at \$10 per cord, and 250,000,000 cords were destroyed during the 10 years of this outbreak, an annual loss of \$250,000,000. Viewed from another point, a cord of wood roughly produces a ton of paper and this paper is valued at from \$60 to \$70 per ton or a yearly loss to the paper industry of at least \$1,500,000,000. A loss that is rather difficult to measure but which will run into very vast figures is that occasioned by the necessity of shifting the pulpwood operations in this country from the northeastern section to the South and West. The pulpwood industry is heavily capitalized and the change of location is a very costly one. The last budworm epidemic preceding the one recorded in this paper occurred about 35 years before it, so in order to get a fairer distribution of the loss we spread the damage over the period of outbreaks. If a loss of this magnitude occurs in 10 years out of 35, it will average \$71,400,000 per annum on the raw product.

In a recent publication of the Forest Service (Statistical Bulletin No. 21) very careful estimates by the Bureau of Entomology on the damage done by insects to the several types of forest products, as ties, poles, cooperage, etc., range from 0.5 per cent to 5 per cent, and in the aggregate losses of this type amount to \$46,900,000.

As other defoliators cause damage estimated at about \$5,000,000 a year, this makes a grand total for insects attacking forests and forest

products of \$138,300,000.

Spruce budworm.....	\$ 71,400,000
Insects attacking forest products.....	46,900,000
Bark beetles.....	15,000,000
Other defoliators.....	5,000,000
	<hr/>
	\$138,300,000

TERMITES

Then there are the termites (Reticulitermes spp.), which on the 6,000,000 farms in the United States are always at work. These insects, however, are much more troublesome in the warmer parts of the country, so we have divided the country into a southern region and a northern region along a line from New Jersey to Nebraska. In the southern part of this territory farm buildings are valued at \$2,900,000,000. It is estimated that the termites in this territory depreciate farm buildings approximately 1 per cent per year; this means that there is an annual loss of \$29,000,000. But the remainder of the country is not immune from termite attack. Illinois, Indiana, New York, and the other States all report damage by these insects. Allowing a depreciation of 0.01 per cent of the total farm buildings in this region, we have an additional \$290,000, or a total of \$29,290,000.

Damage by termites is not confined to the rural districts, but probably a lower percentage of damage of the total building valuation prevails in cities and towns because many of the buildings are constructed of stone, brick, or concrete. It has been found profitable to protect wooden buildings from termites by an additional investment of from 2 to 10 per cent; This means, over 50 years of depreciation, from 0.4 per cent to 0.2 per cent per annum.

STORED-GRAIN INSECTS

It is rather difficult to separate the damage occasioned by the several insects that attack stored grains. Geo. A. Stuart (Gen. Bul. 393, Pa. Dept. of Agr.) estimated that the damage by the Angoumois grain moth (Sitotroga cerealella Oliv.) in Pennsylvania alone ran from \$1,000,000 to \$3,000,000 annually. Perez Simmons found in Maryland in 1924, from field examinations of standing grain ripe enough for harvesting, that 0.26 to 2.06 per cent of the wheat was infested by this insect. In 1922 E. A. Back and R. T. Cotton found that infestations at harvest time amounted to 2 per cent, and late threshing gave these an opportunity on many farms to develop to infestations involving from 60 to 90 per cent of the crop.

The rice weevil (Calendra oryzae L.) in 1919, in connection with the Angoumois grain moth (Sitotroga cerealella Oliv.), was found in 70 per cent of the wheat shipments originating in Oklahoma, and in Texas

88.7 per cent of the shipments were infested. During the period 1917-1921, 5 per cent of all of the wheat in interstate commerce was graded down on account of insect injury. The entomologists of the wheat belt estimate that 7 per cent of the wheat is damaged by the Angoumois grain moth alone. Back and Cotton (Farmer's Bul. 1483) report that in 1922-1923, 13 per cent of 7,892 car loads of wheat arriving in Baltimore graded "sample" and in 1923-1924, 20 per cent of 2,860 car-loads graded "sample" on account of the presence of weevils. This wheat was mostly from the Middle Atlantic States. These two seasons, however, were outbreak years, and in 1924-1925 the percentage of car-loads shipped graded "weevily" (the old grade "sample" having been abandoned for weevil injury alone and wheat simply placed in its grade and the word "weevily" added) was 4 per cent, which placed it subject to a discount or expense of conditioning of at least 3 cents per bushel. Allowing 4 per cent of the wheat of the United States (or somewhat over 30,000,000 bushels) to be graded down on account of granary pests, we would have a monetary loss of about \$1,000,000. This does not take into account the actual grain lost. Moreover, it only considers that grain that is actually inspected in commerce, and not the total production, a considerable quantity of which is held on the farm for feeding, seed, or for future sales. Probably a greater loss is occasioned in keeping the grain in condition after it reached the elevators or mills than at the time of inspection.

When infestations are at all severe it is often necessary to screen and blow the grain. These screenings are of very slight value when compared to the whole berry wheat. There is also a secondary effect of infestation of grain due to heating.

In Florida weevil damage to corn was estimated at 10 per cent in 1916 and in South Carolina in 1911 at 13.8 per cent. The entomologists of the Corn Belt have estimated the damage due to two species of *Calendra* at 18 per cent.

In Georgia in 1923 S. E. McClendon found that 42.9 per cent of the ears of corn were infested by the rice weevil before harvesting. Shipments of corn inspected at Sherman, Tex., were found to be infested to the extent of 79.5 per cent.

Assuming the much more conservative of these figures, 10 per cent, as being the damage actually done to corn by granary pests, the 486,000,000-bushel crop of corn grown in the southern part of the country where these insects are important is but 90 per cent of the crop that might have been consumed as food and feed were it not for these insects. That is a loss of 54,000,000 bushels; or, at the 1927-1929 price of about 75 cents per bushel, \$40,500,000 for the South alone. The rest of the country is by no means free. It must be borne in mind, however, that this is not one insect, but the aggregate of several the work of which can not be easily separated.

Taking corn, wheat, and other grains together the damage by stored-product pests must amount to at least \$50,000,000.

CLOTHES MOTHS

Clothes moths (Tineola biselliella Hum. et al.) are usually considered as extremely trifling insects but few have considered the aggregate losses occasioned by them.

To be conservative, we will consider the city and town houses with their cedar-lined closets and housekeeping facilities as immune from these pests. They are not, however.

On the farms of the country there is a population over 10 years old of 21,500,000 people. Of this 21,500,000 there is probably not a soul who has not lost an average 50 cents worth of apparel by these pests every year of his or her lifetime. This would amount to \$10,800,000. Certainly the average loss is far above this figure.

DISEASE-CARRYING INSECTS

Another phase of insect damage is the loss occasioned to people of the United States through insects that carry diseases. A few of the most striking diseases of this type are malaria, yellow fever, ship fever, Asiatic cholera, dysentery, Rocky Mountain spotted fever, and pink eye, in this country.

The ravages of malaria transmitted by Anopheles spp. have been estimated as producing directly and indirectly half of the entire mortality of the human race (Creighton, Encyclopedia Britannica). Sir Patrick Manson, working in tropical countries, says that malaria causes more deaths and predisposition to deaths than all other diseases that attack mankind taken together.

For the period 1900-1907, Dr. Howard published figures (Bur. Ent. Bul. No. 78, 1909) on sixteen northern States where the deaths amounted to 4.9 per 100,000 population and actual deaths for these States to 1,583 persons per year. These are all northern States, and it is recognized that malaria is much less prevalent in the North than in the South. Dr. Howard estimated that for the whole United States, 15 persons per 100,000 is a very fair figure.

But the losses by death are only a small part of the loss occasioned by this disease, as usually it is not of a fatal nature. Studies made at the hospitals of Rome show that the mortality among hospitalized malarial patients amounted to only 7.75 per thousand. In all probability, the number of deaths, considering all the cases of malaria, would be less than 5 per thousand. The great loss is in the time lost by the individual while sick, in the reduced vitality and resistance of the individual occasioned by the disease, and in that factor upon which no value can be set, the comfort and happiness of the individual himself.

Herrick has estimated (Popular Science Monthly, April, 1903) that in the 5 States, Louisiana, Alabama, Mississippi, Georgia, and South Carolina alone, 2,000,000 to 5,000,000 days of sickness are traceable to this one disease, and as a direct result of the prevalence of this disease much of the richest land in America, and probably the second richest area in the world, the Mississippi Delta, is only valued at from \$10 to \$20 per acre. This land can and does produce, when cultivated, from 1 to 2 bales of cotton per acre and should be worth from \$200 to \$300. The limiting factor is malaria. The white man can not comfortably live there.

Sir Ronald Ross has attributed the physical degeneration of one of the strongest races on earth, the Greek, to the introduction of malaria into their country.

As I have said before, the death rate fails to even indicate the economic loss occasioned by this insect. A small item of the cost, namely, screens, amounts to around \$10,000,000 per annum.

If we have a mortality of 15 persons per 100,000 and if the ratio of mortality to total cases under medical care is similar to that in Rome, we should have in this country 1,500,000 persons annually sick with malaria and under medical care, and the total number having the disease would probably be twice that figure.

Dr. G. O. Smith, of the United States Geological Survey, in records made of the topographic field workers of the Survey ascertained that one-fourth of the active capacity of the diseased individual was lost.

Mr. D. L. Van Dine (Amer. Jr. Pub. Health, Vol. 10, No. 2, p. 116-119, Feb. 1920) carried on a very intensive study on the losses to rural industries through mosquitoes in a comparatively small community in Louisiana, where the conditions on 74 farms supporting 299 individuals were analyzed. These studies were made in 1913, at which time the population in this community was classified on an age basis as follows:

	Number Under 8 yrs.	Number 8-12 yrs.	Number 12-18 yrs.	Number over 18 yrs.
Male.....	19	14	29	82
Female.....	24	18	26	87

A careful study of the hospitalized cases showed that during this time there were 970 cases of malaria. In this study an effort was made to ascertain the actual industrial loss occasioned by this disease. Of course, sick children under 8 years were not a direct industrial loss, a child from 8 to 12 years of age was considered as one-fourth of an adult, and all over 18 years old as adults. The computation was made on the basis of adult, male work days, and in the computation, female time was considered one-half that of male time. The time lost was 625.5 days of adult time by hospitalization or under care of a doctor.

Further studies of time lost by cases not reported to doctors, and the time lost by those attending the sick, give a total of 1,066 days, reduced to adult time. In a community of 299 persons this averages 3.56 days per person. The actual time lost by each case of malaria was 6.42 days per year (adult time). Basing our figures on the estimate of 3,000,000 cases of malaria occurring annually in the United States, we have a time loss of 19,260,000 adult days, which, valued at \$2 per day, amounts to \$38,520,000 loss to industry.

LIVESTOCK PESTS

Few entomologists have considered the insects affecting domestic animals as among their important pests.

The screw worm (Cochliomyia macellaria Fab.) has been very carefully investigated by the Bureau of Entomology and the damage is known to be over \$4,000,000 per year. This insect has rendered no longer available for this industry large areas which were formerly productive calf-raising sections. When we consider that range country is not adaptable for immediate transfer to farming activities, the depreciation of real estate values in these areas is a tremendous feature in itself.

The cattle grubs (Hypoderma spp.) are also serious live stock pests. Nineteen per cent of all hides, commercially graded, are classed as grubby, (Dept. Bul. No. 1369, F. C. Bishopp, et al.). Discount for grubby hides is 1 cent per pound, hide weight. Approximately 16,000,000 hides, not counting calf skins, are produced annually of which 3,340,000 are classed as grubby. Cow, steer, and kip hides average roughly 45 pounds per hide, giving a net loss of \$1,500,000 due to hide damage alone. To this must be added the damage in storage indirectly due to grubs, called salt stain, the damage to calf skins and that which occurs in hides early and late in the season which are not included in these figures. Bishopp (loc. cit.) figures this total loss to hides at between \$5,000,000 and \$10,000,000 annually.

This takes no account of annoyance to stock during oviposition of the flies and irritation to the host by the larvae both of which are reflected in reduced milk flow and failure to put on flesh. Death loss which results occasionally from cattle grub attacks also is not included.

About 70 per cent of the beef produced in the United States comes originally from the Southern and Western States, judging from the numbers of cattle other than milk cows on farms. That means approximately 70 per cent of nearly 5,000,000,000 pounds or about 3,500,000,000 pounds, considering only federally inspected beef, which is the greater part of the beef supply. At an average price of 16 cents per pound, this southern and western meat was valued at \$560,000,000. German experiments showed an increase in meat production of 5 per cent in cattle from which grubs had been removed over those which were allowed to remain infested. This is to say, the production of southern and western beef is about 95 per cent of what might have been produced had it not been for these insects alone, or a loss of nearly \$30,000,000.

Dairymen estimate loss of milk at from 10 to 25 per cent during the period of fly activity (1 to 4 months), 10 per cent loss in 2 months' milk amounts to 250,000,000 gallons worth at bulk farm prices \$60,000,000.

Collecting all the losses occasioned by cattle grubs and other flies we have:

Loss to dairy products.....	\$60,000,000
Loss in beef.....	30,000,000
Damage to hides.....	5,000,000
	<hr/>
	\$95,000,000

Table I

Summary of Annual Losses Occasioned by 34 of the More Important
Insect Pests of the United States

Insect	Crop attacked	Damage occasioned by insect.
<i>Anthonomus grandis</i>	cotton	\$ 164,500,000
<i>Heliothis obsoleta</i>	cotton, corn, tomato, and tobacco	104,000,000
<i>Harmoloba fumiferana</i>	pulpwood	71,400,000
<i>Empoasca fabae</i>	potato	11,000,000
<i>Phytophaga destructor</i>	wheat	48,000,000
Acrididae	truck, cereals	50,000,000 (Marlatt)
<i>Calendra oryzae</i> et al.	wheat, corn	50,000,000
<i>Hypoderma</i> spp.	cattle	35,000,000
<i>Lyctus</i> spp. et al.	forest products (not buildings)	17,600,000
<i>Blissus leucopterus</i>	corn, wheat	50,000,000
<i>Leptinotarsa decemlineata</i>	potato	29,000,000
Culicidae	man	38,500,000
<i>Haematobia irritans</i> et al.	dairy products	60,000,000
Termites	woodwork	29,300,000
<i>Diabrotica 12-punctata</i>)	corn	20,000,000 (Marlatt)
<i>Diabrotica longicornis</i>)	deciduous fruit	17,000,000
<i>Conotrachelus nemuphar</i>	apple, pear, peach	30,000,000
<i>Carpocapsa pomonella</i>	apple	8,200,000
<i>Aphis pomi</i> et al.	cereals	15,000,000 (Marlatt)
<i>Cirphis unipuncta</i>	coniferous trees	15,000,000
Bark beetles	clothing et al.	10,800,000
<i>Tineola biselliella</i> et al.	cotton	8,000,000 (Marlatt)
<i>Alabama argillacea</i>	deciduous fruit	7,400,000
<i>Aspidiotus perniciosus</i>	peach	6,000,000
<i>Aegeria exitiosa</i>	truck, cereals	5,000,000 (Chittenden)
Elateridae	cattle	4,000,000
<i>Cochliomyia macellaria</i>	citrus	4,000,000
<i>Saissetia oleae</i>	sugarcane	4,640,000
<i>Diatraea saccharalis</i>	peas	2,100,000
<i>Illinoia pisi</i>	citrus	2,400,000
<i>Chrysomphalus aurantii</i>	melons (excepting cantaloupe)	2,000,000
<i>Diabrotica vittata</i>	beans	1,600,000
<i>Epilachna corrupta</i>	cabbage	3,000,000
<i>Pieris rapae</i> et al.		
Total		\$924,440,000

Table II

Boll Weevil Damage to Cotton as Estimated by the
U. S. Bureau of Crop Estimates.

Year	::Annual loss of cotton expressed : ::in terms of weighted average per-: Other : ::centages of the estimated crop in: Insects : Total ::the absence of insects :		
	Per cent	Per cent	Per cent
1910	5.30	2.20	7.5
1911	1.28	6.62	7.9
1912	3.26	3.24	6.5
1913	6.69	2.21	8.9
1914	5.91	3.89	9.8
1915	9.93	2.27	12.2
1916	13.36	2.34	15.7
1917	9.34	2.96	12.3
1918	5.83	2.07	7.9
1919	13.20	5.60	18.8
1920	19.95	4.05	24.0
1921	30.98	4.42	35.4
1922	24.17	2.53	26.7
1923	19.55	7.05	26.6
1924	8.01	3.99	12.0
1925	3.87	2.23	6.1
1926	7.04	8.90	15.9
1927	18.50	4.40	22.9
1928	14.10	3.40	17.5
Average	11.59	3.91	15.5

